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A Biological Investigation of an Organically Polluted Urban Stream in Victoria

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Abstract

The macrofauna of Dandenong Creek, an organically polluted urban stream in Victoria, was studied. It was difficult to separate effects due to pollution from those due to other forms of interference. No true indicator species were found, but seven groups of common animals could be arranged in order of increasing pollution tolerance. Some of the difficulties of using biological systems for stream monitoring are discussed.

Introduction

Much concern about stream pollution stems from the effects of pollution on the stream biota. Conversely, however, natural changes induced by pollution of stream biota provide a method for assessment of the pollution; biological examination may give a more accurate picture than physicochemical examination (Hirsch 1958; Hynes 1960, 1964*a*, 1964*b*, 1965). Several authors note that invertebrates may be most useful in this context (Hynes 1965; Hussainy and Abdulappa 1967) because of relative immobility, life-cycle length, and ease of sorting and preservation. However, Hynes (1960) comments that invertebrates may be much less useful in heavily polluted waters.

A serious water pollution problem in Australia involves small urban streams. Largely, this problem is caused by sullage and septic tank overflow (Senate Select Committee Report 1970). The biological effects of such pollution have not been studied in Australia, and thus water quality management decisions on these streams are based on limited physicochemical and bacteriological data alone, even when stated management policy aims include the preservation of 'habitat for fish and aquatic life' (Environment Protection Authority, Victoria 1972).

The investigation reported here concerns Dandenong Creek, a small stream rising in a relatively undisturbed area east of Melbourne, Vic. It flows through unsewered and partly sewered suburbs, where it is polluted by sullage, before entering Port Phillip Bay. This stream appears particularly suitable for the study of sullage effects on macro-invertebrates in lowland streams. In this paper, the water quality and benthic macro-invertebrate community of the stream are described, and the applicability of some biological indices of water quality are examined.

Only four studies have been published on the biological effects of pollution on Australian streams. Two studies were of streams polluted by heavy metals (Weatherley *et al.* 1967; Thorp and Lake 1973), and the third was of two highland streams polluted with organic material (Jolly and Chapman 1966). Biological data from these studies are of limited applicability to organically polluted lowland streams. The fourth study, that of McIvor (1976), was of a stream in Queensland with a markedly different fauna to that of streams in south-eastern Australia.

Data are available on the biological effects of organic pollution on streams in most regions of the world. Hynes (1960) summarized the work done before 1959, and Hynes (1965), Bartsch and Ingram (1966), Wilber (1969), Warren (1971) and Goodnight (1973) have reviewed much of the work done since, especially in America. Studies have been carried out in New Zealand by Hirsch (1958), Johanesson (1958) and Cameron (1970). However, because of the uniqueness of Australian stream faunas (Bayly and Williams 1973), much of the overseas data are of doubtful applicability in this country.

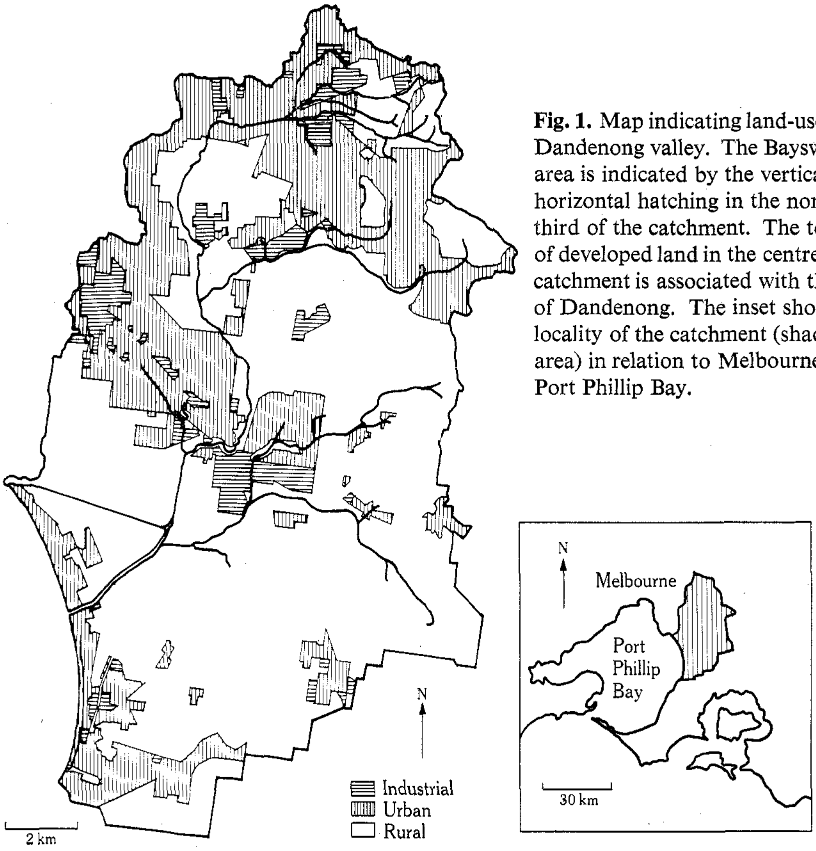

Fig. 1. Map indicating land-use in the Dandenong valley. The Bayswater area is indicated by the vertical and horizontal hatching in the northern third of the catchment. The tongue of developed land in the centre of the catchment is associated with the City of Dandenong. The inset shows the locality of the catchment (shaded area) in relation to Melbourne and Port Phillip Bay.

The Study Area

The Dandenong valley lies about 20 km south-east of Melbourne, Vic. It forms a shallow trough between the Yarra valley to the north-west, and the Dandenong Ranges and the hills of the Mornington Peninsula to the east and south. About 880 km^2 in area, it consists mostly of Recent clays and silts, with some basaltic areas on the slopes of, and adjoining, Mount Dandenong.

Mostly the valley is used for agriculture, primarily dairying. However, quite large areas are urbanized, principally around Dandenong and further north around Bayswater (Fig. 1). Both urban areas are rapidly expanding. Many premises in the valley are either not connected to existing sewers (7·4%), or are in unsewered areas (52%). A small part of the catchment, on the slopes of Mount Dandenong, is State Forest.

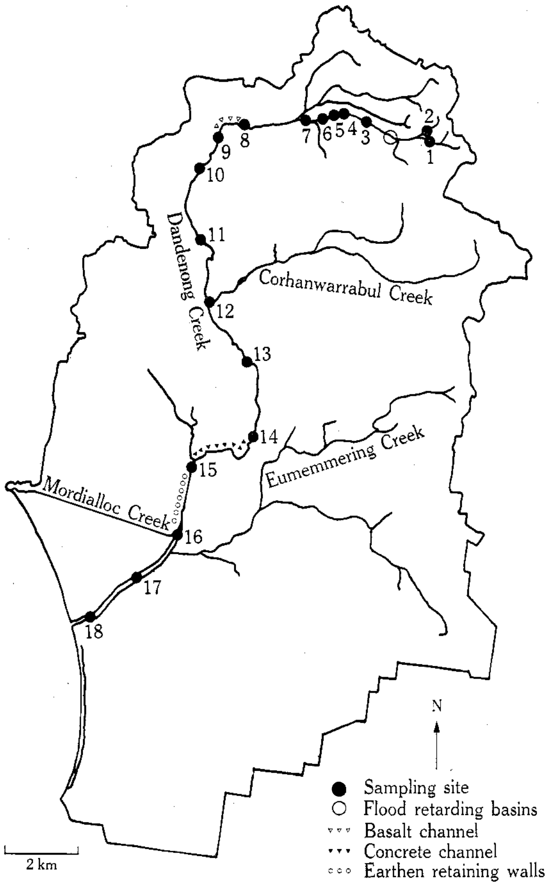

Fig. 2. Map of the larger streams in the Dandenong valley, with the locations of sampling stations and major human modifications of the stream channel indicated.

The valley was originally drained by two major creeks—Dandenong Creek and the smaller Eumemmering Creek (Fig. 2). These flowed into extensive coastal swamp areas drained by Mordialloc Creek, Patterson River and Kananook Creek. Much of the swamp has now been drained; Dandenong Creek has been connected to Patterson River, making it, in effect, the same stream. This is by far the largest stream, draining some 68% of the valley. Urban areas in its catchment are largely unsewered, 15% (6300) of premises in sewered areas are unconnected, and a further 62 000 premises are in unsewered areas. In the catchment of this stream also, rapid urban growth is taking place.

The Dandenong Creek itself is a small turbid stream, 35 km long, rising near Mount Dandenong. After a short, stony erosional stage it becomes depositional with a series of pools with muddy bottoms. The pools are mostly about 1 m deep and 2–3 m wide, and are connected by shallower, more rapidly flowing stretches. This pattern presumably continued for the rest of the stream before human interference. Modifications of the creek, aimed at flood control, have speeded up the flow in much of the creek, converting it to an erosional type with a scoured clay and packed silt substratum.

The creek is subject to severe fluctuations in flow. It occasionally dries up to a series of pools in summer, and is subject to flooding in all seasons. The Dandenong Valley Authority was established in 1964 as a flood mitigation agency, and has carried out various modifications to much of the creek. These modifications range from removal of obstructions to complete barrelling of a short section.

About 5 km of the stream has artificial concrete or stone banks with an essentially natural bed, whilst through Dandenong another 6 km is a concrete channel. All the creek below the concrete channel runs through an earthen canal, constructed when the adjacent swamps were drained (Fig. 2).

Methods

The stream was sampled for 15 months at 19 stations (Fig. 2). The upper 11 stations were sampled monthly from June 1971 until June 1972; the lower 8 stations were sampled less intensively from June 1971 until August 1972. The physical characteristics of each station are indicated in Table 1. At each sampling, the levels of biochemical oxygen demand (BOD), dissolved oxygen, pH and temperature were recorded. In addition, counts were made of the numbers of coliform bacteria and *Escherichia coli*. Bottom sediment samples were also taken, and collections of animals in the littoral vegetation were made.

Stream water levels were monitored intermittently by the Dandenong Valley Authority between stations 2 and 3 (Fig. 3).

Dissolved oxygen and oxygen for the BOD tests were determined by the azide modification of the Winkler technique (American Public Health Association 1971). BOD samples were incubated for 5 days. From June to December 1971, pH was determined in the laboratory on a Pye Dynacap meter; after December, a Beckman Zeromatic meter was used. Water temperature was measured using a mercury–glass thermometer. Numbers of bacteria were determined using the techniques outlined by the Public Health Laboratory Service Standing Committee (1969).

Biological samples were collected by sweeping a coarse pond net, mesh size 0·56 mm, through littoral vegetation for 2 min, or until about 200–300 animals had been collected. One or two sweeps were sometimes sufficient to obtain thousands of individuals. Samples were preserved in the field using 70% ethanol, and sorted in the laboratory.

Results

Physicochemical Results

Results from the water-level recorder operated by the Dandenong Valley Authority are shown in Fig. 3.

Water temperature normally increases downstream (Talling 1957; Minckley 1963; Hynes 1970), and this phenomenon can be seen in Fig. 4*a*. Other effects may be superimposed on this pattern, as in this case, the most important effect being the presence and type of fringing vegetation. The rate of increase of temperature increases markedly between stations 6 and 8, where fringing trees have been removed, whilst the temperature falls between stations 9 and 10 when the stream enters a section where the fringing vegetation is quite dense and has been allowed to remain. One factor causing the temperature decrease between stations 16 and 17 may have been a decrease in the rate of flow, causing a noticeable decrease in turbidity. Turbid

Table 1. Descriptions of the sampling stations

Stn No.	Substrate type	Current[A]	Depth (cm)	Breadth (m)	Features
1	Sand and scoured mud, abundant dead leaves	1	50	1	Flows through pastures above station 1 and is lined with tree ferns and exotic trees.
2	Stones	4	5	1	Emerges from the State Forest *c*. 1 km above station 2, flows through narrow cutting 3 m deep, lined with dense growths of native vegetation and blackberries.
3	Scoured mud and clay, some leaves	2	50	2	Flows through pasture after station 1 in cutting similar to that described above but only 2 m deep. An earthen flood-retaining wall has been built 1 km below station 2.
4	Scoured mud and clay	2	50	2·5	Flows through pasture in cutting 2 m deep.
5	Scoured clay	3	30	3	Emerges from cutting 10 m above station 5, lined with *Elodea*, flows into barrel drain 2 m below station. Land use from stations 4 and 5 pastoral and light industrial.
6	Sand and small stones	4	25	1·5	Emerges from drain 20 m above station, and no bordering vegetation. Land use from stations 5 and 6 light industrial.
7	Small stones	4	25	1·5	Station located only 50 m below station 6, below outfall of Bayswater main drain.
8	Basalt	3	25	5	Bordered by tip and housing estate, no fringing bushes or trees. Croydon main drain outfall 800 m below station 7.
9	Mud	1	30	7	From stations 8 and 9 rapidly flowing in basalt canal which terminates 10 m above station 9. Land use agricultural and unsewered urban.
10	Scoured mud	3	30	5	From stations 9 and 10 unstraightened bordered by 100–150 m native bushland on either side.
11	Scoured mud	3	50	3	From stations 10 and 11 native bushland continues. Nunawading city tip located adjacent to 0·5 km below station 10.
12	Scoured mud	4	70	10	Below station 11 adjacent land becomes flatter and more swampy. Fringing vegetation changes to *Leptospermum* and *Salix* spp.; Corhanwarrabul creek joins the main stream 50 m above station 12.
13	Scoured clay	5	50	2	Below station 12 the fringe of bordering vegetation broadens, the willows disappear and *Melaleuca* spp. become common.
14	Scoured clay, concrete	3	20	5	Little change from the previous station. Land use immediately bordering the stream is pastoral.
15	Concrete	5	30	2	The concrete channel begins at station 14 and carries the water through Dandenong; station 15 is situated 200 m past the edge of the urban area of that city.
16	Scoured clay	4	100	5	Station is situated 2 km below the end of the concrete channel and 2·5 km below Dandenong Sewage Treatment Works in pastoral land.
17	Sand	3	30	3	Land use between stations 16 and 17 is pastoral. Construction of M.M.B.W. sewage treatment works was commenced adjacent to the station 17 during the study period.
18	Mud	1	300	60	Estuarine, bordered by urban development. Land use between stations 17 and 18 is pastoral.

[A] Current speed is expressed in terms of a comparative scale from 1 to 5 with 1 being the slowest speed and 5 the highest.

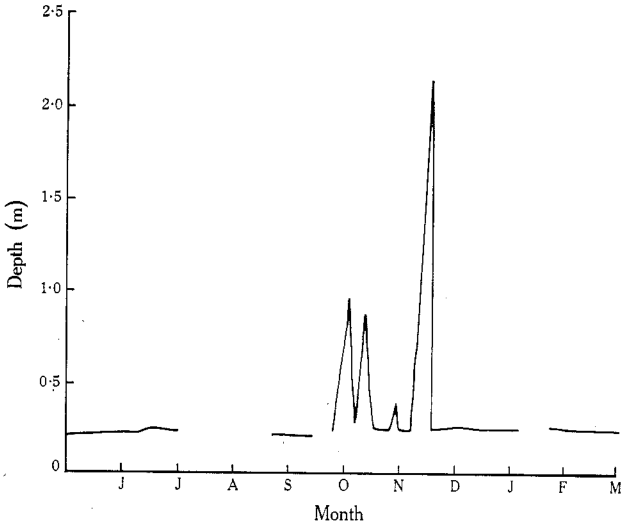

Fig. 3. Water level variations near sampling site 3 between May 1971 and March 1972.

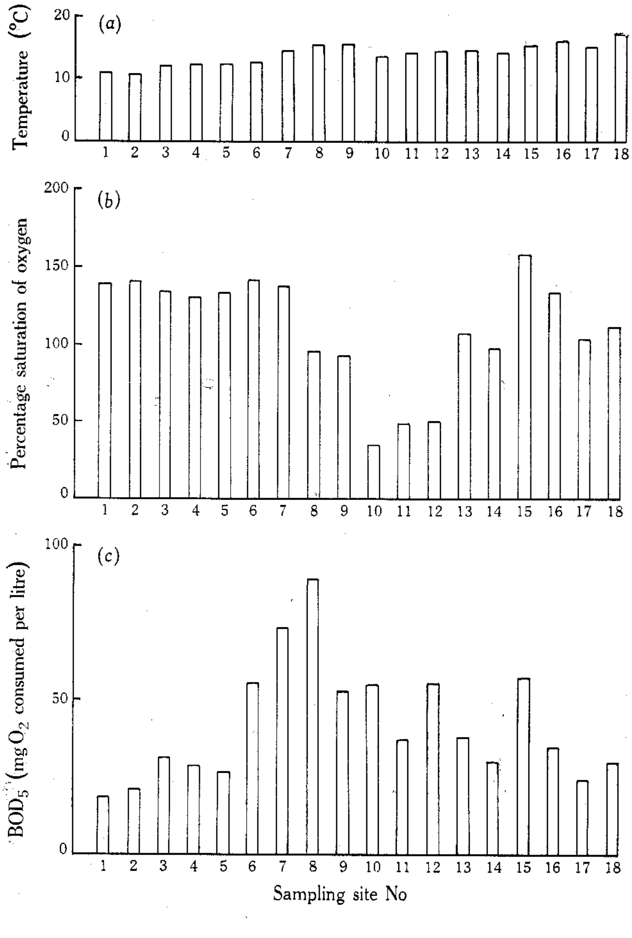

Fig. 4. Means of the 13 monthly (*a*) temperature readings, (*b*) oxygen determinations, and (*c*) BOD_5 determinations for each sampling site.

streams have a greater heat capacity than clear ones (Hynes 1970), and thus some of the heat load may have been discharged, especially in summer. The monthly record of temperature simply reflected ambient air temperatures for the months in which sampling took place.

Dissolved oxygen data are shown as percentage saturation (Fig. 4*b*). The average of all the monthly values of saturation was above 100% at 12 stations, being fairly even around 140% for the first 7 and then more erratic. In shallow, turbulent streams, dissolved oxygen levels are normally at 100% saturation or greater (Hynes 1970). Minckley (1963), for example, recorded a maximum level above weed beds in Doe Run of 191%, and Gaufin and Tarzwell (1956) recorded a maximum concentration of 19·4 ppm in Lytle Creek without noting the temperature at which it occurred.

It was thought that photosynthetic activity may have been partly responsible for the peak at station 15 (Fig. 4*b*), since the substratum at this station is covered with a layer of algal slime. In order to test this, two series of oxygen determinations were performed. The first of these was performed at hourly intervals from 1600 to 2000 h, with sunset at 1735 h; the second was taken from 0300 to 0900 h, at 3-h intervals. Both these sets of determinations showed higher percentage saturations during the light period.

At no other station were the attached algae as evident as they were at station 15. Presumably, therefore, photosynthesis as a source of dissolved oxygen was less important at all other stations.

Where major increases in BOD occur between stations (Fig. 4*c*), they seem explicable. The small peak at station 3 is largely due to a reading of 71·0 in November 1971. The high level was probably caused by eroded material washing in from the newly constructed flood-retarding basin, during the floods between 7 and 10 November 1971. Between stations 5 and 6 a number of stormwater and factory effluent drains enter the creek, and the Bayswater and Croydon main drains enter the creek above and below station 7 respectively. Corhanwarrabul Creek enters the stream just before station 12, and station 15 is immediately downstream of Dandenong.

BOD values were higher in the spring and summer months than in the other two seasons. This may be because rainfall in these seasons tended to occur in short heavy bursts, and would thus have washed more material into the stream than would lighter, more prolonged rainfall. On the other hand, the floods resulting from these heavy showers would also tend to flush the creek out and remove organic material.

Very little longitudinal variation occurred in pH values, mean monthly values ranging from 6·4 to 7·0. Variations between months showed a greater range (5·9–7·4), but no apparent pattern of variation.

Biological Results

Levels of coliforms and *Escherichia coli* were found to be high in the Dandenong Creek, with a peak of over 10^6 coliforms at stations 7 and 8 (Fig. 5). *E. coli* peaked at 4×10^5 at station 8. The high number of coliforms at station 1 may be due to run-off from a nearby cattle holding allotment.

Little annual periodicity was evident. *E. coli* numbers generally decreased as the study progressed, whilst the more erratic total coliforms increased. Many factors can affect stream bacterial numbers, including temperature, BOD, and flow rate (Daubner 1969). High temperatures may well have been a factor in the high numbers of both groups found in December.

The main obstacle to the study of macro-invertebrates in Australian streams is lack of taxonomic knowledge, a situation previously commented upon by several workers (e.g. Williams 1976). Very few animals found in this study could be identified to species, and most not beyond family with certainty.

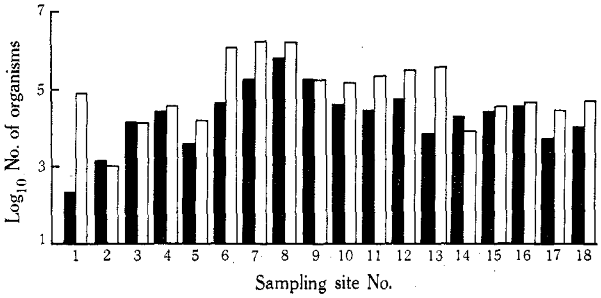

Fig. 5. Means of the 13 determinations of the numbers of coliform bacteria (outline bars) and *Escherichia coli* (solid bars) at each sampling site.

The distributions of the most abundant invertebrates are indicated in Table 2. Fig. 6 compares the relative abundance of the seven most abundant species, or species groups, at each station. No animals were collected at stations 14 or 15 due to the nature of the substrate (see Table 1).

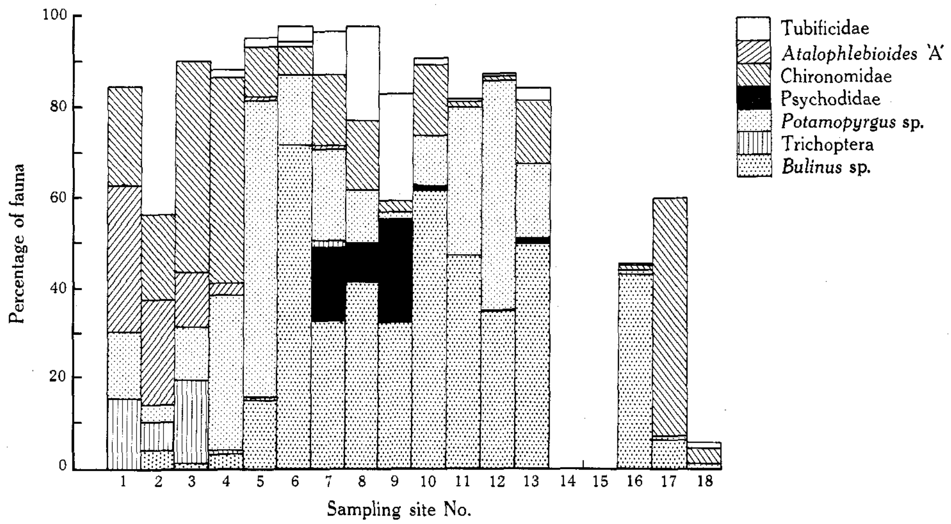

Fig. 6. Relative abundances of the seven overall most abundant species or species groups at each sampling site. It should be noted that the percentage abundances of the species are 'stacked' and not cumulative, i.e. *Atalophlebioides* 'A' comprises 32% of the sample at station 1, not 62%. No results are given for stations 14 and 15, since the concrete channel forming the creek bed at these stations was devoid of macrofauna.

Discussion

Chemical Characterization of Pollution

If increases in BOD and bacterial levels, together with a decrease in oxygen concentration, are considered indicative of increasing pollution, then Dandenong

Creek becomes increasingly polluted from stations 1 and 2 to stations 8, 9 and 10, after which it shows some recovery. The gradual increase in pollution from stations 1 and 2 to 5 is due, no doubt, to numerous small drains from paddocks and isolated houses and factories. Stormwater drains from a light industrial area and associated housing probably account for the increase between stations 5 and 6; and the Bayswater main drain, previously mentioned, contributes to the increase between stations 6 and 7. Between stations 7 and 8 the Croydon main drain and a number of smaller drains enter the stream, and, from station 8, the first several hundred metres of stream are bordered by a tip, which doubtless contributes to the pollution load both through runoff and seepage. The influence of tips on adjacent streams has been documented by Nuttall (1973).

The sequence of pollutional processes in the upper section of this creek is thus similar to that found in the River Derwent in the United Kingdom by Brinkhurst (1965), but is different from that in many of the other overseas studies, such as those of Gaufin and Tarzwell (1952, 1956) and others. In the latter study the stream studied had a single point source of pollution, and below this the degree of pollution decreased downstream. The nature of the pollutants changed also, mineralization increasing downstream. This change is, in fact, the basis for one of Bringmann and Kuehn's (1956) physiological methods for assessing pollution. In the present study, however, the greatest degree of mineralization occurred at, or immediately adjacent to, the worst polluted stations rather than some distance from them. This is not unusual, several authors having previously commented upon it (Downing 1962; Brinkhurst 1965), and is probably related to physical factors. For example, although BOD and bacterial levels reached their peak at station 8, dissolved oxygen levels reached their minimum 4·5 km lower down. Downing (1962) noted that, depending on the nature of the organic material discharged, de-oxygenation may occur many miles downstream from the source of the material. In Dandenong Creek the organic material did not consist of synthetic compounds not readily amenable to biodegradation of the sort to which Downing referred, and the shallowness and turbulence of the stream between stations 8 and 9 was probably the major factor in preventing an oxygen deficit. Allanson (1961) found the same phenomenon in his study, and attributed it to the same cause. In Dandenong Creek below station 9 the stream meanders with a decrease in flow rate and an increase in depth, and, consequently, by station 10 there is a considerable oxygen deficit.

In streams polluted at a single point, as in most theoretical models (Bartsch 1948; Bartsch and Ingram 1959; Klein 1959; Hynes 1960; Curtis and Harrington 1970), it is simple to decide on the relative degree of pollution at points downstream: the point just below the source is the most polluted, and subsequent points are progressively less polluted. Unfortunately, such situations are rare, sources of pollution generally being multiple and frequently diffuse. The investigator may then be confronted with the problem of evaluating pollution on the basis of conflicting data. Mostly, where such evaluations have been made they are subjective; however, at least some attempts have been made towards increasing the objectivity of these evaluations (Prati *et al.* 1971).

For water quality surveillance, the problems raised may not be important. The chemist can, after all, characterize water with a chemical description containing more information than a single index, but for a biologist trying to associate species or communities with degrees of pollution the problem may be acute.

Table 2. Distribution of the most abundant invertebrate taxa in Dandenong Creek

Results are expressed as percentages of the total number of organisms found at each particular station over the whole period of the study. Where a taxon was present but made up less than 1% of the total number of organisms present the result is indicated by the symbol +

Taxon	Station: 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Annelida																		
Haplotaxiidae						+	+	1·7	9·4	+						+		
Naididae		1·5		+								+	+			20·5		5·0
Tubificidae	+		+	1·4	1·6	4·2	9·3	20·2	23·8	1·4	+	4·1	2·4			10·9	+	2·3
Crustacea																		
Amphipoda	2·4	22·2	1·8		+				+		+	+	+				1·4	+
Sphaeromidae																	1·6	41·2
Insecta																		
Coleoptera																		
Dytiscidae ‘B’		+	+	+			+	+	+	+		+	+			1·8	+	+
Helminthidae	1·5	4·3	3·4	2·6	+	+	+			+		+	+					
Helodidae	+	+	+				+				+	+					+	+
Diptera																		
Chironomidae	22·3	19·4	45·4	47·8	12·8	6·3	17·7	5·9	3·3	12·0	1·0	1·1	15·2			1·8	53·0	3·5
Culex sp.						+		+	1·6		+							
Culiseta sp.								3·2	2·2				+				+	
Psychodidae ‘A’			+	+	+	1·0	15·5	8·5	22·6	+	+	+	+				+	
Tipulidae ‘A’	+	3·7	+	+	+					+								

Ephemeroptera																		
Atalophlebia australis	+	+	+	+	+	+												
Atalophlebioides 'A'	32·1	22·7	11·7	2·3	+	+	+	+										
Baetis sp.	+	+	+	+	+	+	+			+			+				+	
Odonata																		
Chlorolestidae	1·6	+			+	+	+				+	+	+			+	2·3	+
Aeshnidae	+	+	+	+													+	
Plecoptera																		
Illiesoperla australis	1·3	2·4	+	+														
Trichoptera																		
Hydropsychidae											+		5·8					
Leptoceridae 'A'	2·5	+	+	+	+		+						+					
Rhyacophilidae	1·7	1·4	4·5	+	+													
Sericostomatidae 'A'	8·6	2·9	13·3	+	+													
Mollusca																		
Bivalvia																		
Sphaerium sp.		+	+	1·7	1·4	+	+		+	+	9·3	2·2	1·6			+	1·3	
Gastropoda																		
Bulinus sp.	+	4·0	1·3	3·0	14·9	70·6	32·6	40·6	32·0	65·8	47·3	34·9	49·5			43·2	5·9	4·5
Lymnea sp.																	+	6·3
Pettancylus sp.	1·0		+	2·4	+	1·5	+		1·7	+	6·7	+	+			+		
Potamopyrgus sp.	14·8	3·9	11·8	34·1	64·3	15·2	20·0	6·2	1·2	19·8	33·2	51·2	12·6			+	+	1·2

Biological Characterization of Pollution

Some changes in the fauna were evident along Dandenong Creek from stations 1 and 2 to stations 8, 9 and 10. These changes were of two types—changes in species composition and changes in community structure. Both of these types of changes may be induced, either by human activities or by natural changes in the stream habitat, and it is difficult to isolate the effects of human activities.

Changes in species

The most abundant taxa may be listed in order as follows, according to the increasing relative degree of pollution of the station or stations of their greatest abundance: *Atalophlebioides* (Ephemeroptera), Trichoptera (excluding Hydropsychidea and Hydroptilidae), Chironomidae, *Potamopyrgus* (Gastropoda), *Bulinus* (Gastropoda), Tubificidae, and Psychodidae. All groups listed occurred over a wide range of conditions; none could be described as an indicator species in the sense of being stenoecic for a particular degree of pollution, or even for an absence of pollution.

The change in species composition downstream was gradual, no distinct faunistic zones occurring. Chironomidae, *Bulinus* and *Potamopyrgus*, for example, each contributed more than 10% of the fauna at 10 of the 16 stations. This lack of precise zonation may have been due to the difference in the pollution sequence in Dandenong Creek, but it is more likely that the zonation reported in some other studies (Kolkwitz and Marsson 1908, 1909; Campbell 1939; Brinley 1942; Whipple 1947; Gaufin and Tarzwell 1952, 1956; and others) is, in fact, not real; Richardson (1929) had much earlier disputed the existence of such zones.

Changes in communities

A number of authors have stressed the importance of changes in whole communities, in organic pollution studies (Patrick 1950; Gaufin and Tarzwell 1956; Hawkes 1962; Fjerdingstad 1964; Wilhm and Dorris 1968; Cairns *et al.* 1972). These changes may be categorized as follows:

(1) A decrease in the number of species (i.e. in species richness).
(2) Dominance of the community by one or two species (i.e. a decrease in species evenness).
(3) Changes in the overall abundance of the fauna—with extreme pollution this may amount to eradication of the fauna in part of the stream, and, in less severe cases, an enormous increase in animal biomass.

A number of workers have proposed methods by which these changes may be compared. Patrick (1949, 1950) proposed a graphical method, using a comparison of relative abundances of seven groups of organisms in polluted waters with their abundances in clean waters. The groups were based on known or presumed responses to organic pollution. Wurtz (1955) proposed a similar method involving five groups of organisms based on their 'life-forms' e.g. all of the burrowing animals were grouped together. Several authors have developed methods based on species evenness concepts; these include the graphical method of Patrick (1949) and a mathematical method proposed by Allanson (1961).

Species diversity indices are theoretically based on a combination of species richness and species evenness components (Pielou 1969), thus containing two of the elements altered by pollution. Wilhm (Wilhm and Dorris 1968; Wilhm 1972) commends the use of indices, but one problem with these is that where the numbers of animals are repressed or the sample sizes are small for some other reason the indices may give misleading results.

Two such indices were applied to results obtained in the present study—those of Shannon and Weaver (1963) and Simpson (1949). The indices are compared in Table 3, alongside some values quoted by Wilhm (1972) from studies in America. Both the indices gave high values at stations 7, 8 and 9, where pollution was at its greatest. In contrast, the average number of species collected per trip gave a much more useful indication of water quality.

Table 3. Species diversity indices calculated for sampling sites on Dandenong Creek compared with some indices calculated for streams in the U.S.A. by Wilhm (1972)

Station	Number of species	Number of individuals	Mean No. of species per sample	Number of individuals/ No. of species	Shannon diversity index	Simpson diversity index
1	47	2388	12·3	50·8	2·2	0·82
2	47	1022	10·3	21·7	2·4	0·85
3	40	2243	9·7	56·1	1·9	0·76
4	35	1837	8·3	52·5	1·5	0·76
5	39	5608	10·0	147·1	1·2	0·55
6	23	1562	6·2	67·9	1·1	0·47
7	24	789	4·5	32·9	1·7	0·79
8	15	402	3·9	26·8	1·7	0·76
9	18	509	4·2	28·7	1·8	0·78
10	19	4986	4·5	262·4	0·98	0·51
11	18	1727	4·4	95·9	1·5	0·65
12	33	4465	7·6	135·3	1·3	0·62
13	42	1888	7·1	44·9	1·8	0·71
16	18	220	3·3	12·2	1·8	0·75
17	43	2386	10·1	55·5	1·6	0·67
18	32	600	8·6	18·8	2·3	0·80
Clean stream, Colorado	29	236			4·0	
Clean stream, Virginia	28	1320			2·6	
Polluted stream, Virginia					0·53	
Polluted stream, Georgia					1·0	

Sládeček (1972, 1973) has described the longitudinal changes occurring in streams as successions. He proposed that the normal series of changes occurring downstream was a primary succession proceeding through a number of serial states to a naturally eutrophic climax stage. He suggested that the climax may be α-mesosaprobic. This was compared to the theory of increasing eutrophy of lakes with age (e.g. Welch 1952).

Such successions in lakes, caused by forces acting from outside the system, have been called allogenic successions by Odum (1971). The more usual sense in which succession is used is in the sense of autogenic succession—changes created by influences acting from within the system. In any event the longitudinal changes occurring down a river or stream are not a succession in either sense. The term succession refers to a change in time rather than a change in space. A true secondary succession may occur in a stream when an effluent is first introduced or when it is stopped, but once the stream community has adapted to the presence of the effluent the system is held in a steady state (Wuhrmann 1972) which could probably best be described as a dis-climax.

The succession which occurs when the effluent input is eliminated is an autogenic succession. The climax of this succession is an oligotrophic state, not a eutrophic state as suggested by Sládeček, and this change is comparable with successions in other ecosystems, e.g. towards greater diversity and niche specialization.

Conclusions

Implicit in many discussions of stream repurification is the assumption that chemical variables change predictably, and that the biologist's problem is simply to relate biological and chemical changes. However, it is not true that in Dandenong Creek variations in chemical factors are predictable from other chemical factors. This is due partly to the multiple and diffuse nature of the pollution source, and partly to physical variability in the stream. Other workers report the same elsewhere (e.g. Klein 1959). Thus, water quality cannot be defined in terms of a single parameter; it can only have meaning as a total description of the chemical, physical and biological state of the water. Possibly, stream communities may be used to integrate all chemical and physical properties, but probably such integration would be of limited use. In any event, before this could be done much work is needed on defining the effects of different chemical, physical, and even biological factors on stream communities. Results from work like this in Europe and North America may be broadly applicable to Australia, but will have to be applied cautiously.

A list of the most abundant invertebrate groups found during the study, arranged in order of increasing tolerance to organic pollution, was compiled. This list was drawn up on the basis of the stream becoming more polluted from stations 1 and 2 to station 10, and then recovering somewhat. Whilst a clear progression in the most abundant species could be seen in the upper section of the stream at least, the chemical assessment of pollution was fairly subjective, because of the variability of the different chemical parameters measured.

The chemical variability and physical variation do not permit the delimitation of pollution zones in Dandenong Creek on a physicochemical basis. It would be possible to designate 'zones' according to species listed in Table 3, but such zones would be indistinct due to species overlap, and would not necessarily be applicable to other streams. Such zones would give only a broad indication of the chemical state of the stream.

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